462

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FACTORS INFLUENCING IRRIGATION IN HUMID AREAS

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IRRIGATION AND DRAINAGE DIVISION

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FACTORS INFLUENCING IRRIGATION IN HUMID AREAS

Tyler H. Quackenbush[1]

In order to maintain our leadership in the free world, we in the United States must maintain and use wisely the abundant natural resources with which this country was endowed. Probably the two most important of these resources are our soil and water, both of which are involved in irrigation agriculture. The productive ability of thousands of acres of our fertile land has already been destroyed or severely damaged through the misuse of irrigation water. We are now in the somewhat illogical position of constructing irrigation systems and developing new lands for irrigation, while at the same time we are abandoning acre after acre of formerly good fertile soil, for which adequate irrigation water is available but which is now unfit for cultivation due to the accumulation of alkali and the need for drainage.

There are approximately 26,000,000 acres of irrigated land in the United States, involving a capital investment of $1,868,300,000. Yet the average efficiency of irrigation, from the time the water is diverted into the main canal until it is stored in the root zone of the plant, is only 25 percent. Yes, 75 percent is wasted through ditch losses, coupled with deep percolation and surface runoff on the farm. We cannot expect to hit 100 percent efficiency, but it is recognized by all the people concerned that there is certainly ample room for improvement.

We are making progress towards the conservation of land and water in the irrigated areas of the West. Organized research is giving us many of the answers we need. This and an aggressive action program by the water users themselves are the basic elements in our program to improve irrigation practices in the Western states.

We certainly should take advantage of the known mistakes made Out West and make every effort to get started on the right foot here in the East. It is worthy of considerable effort on the part of all of us. It is much easier to instruct a farmer who has never irrigated before on proper irrigation practices than it is to teach one who has been irrigating wrongly for many years.

The latest Census report shows that we now number 157 million. The Bureau of the Census estimates that by 1975 the United States will have a population of 190 million. No one can tell for sure, of course, how accurate these estimates for the future will turn out to be, because the controlling social and economic factors involved do not lend themselves to precise slide rule calculation. But by even the most conservative forecasts of our population's growth, America's agricultural capacity to produce must be increased substantially in the years ahead. Your job and mine in helping to expand and maintain agriculture's capacity to produce presents a challenge worthy of our best talents.

Irrigated agriculture in the eastern United States, if properly guided during its growth, offers one of the largest potentials available for increasing our productivity from the more or less fixed acreage of cropland and pasture land we have available.

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1. Irrigation Engineer, Soil Conservation Service, Washington, D. C., Paper presented to A.S.C.E., Atlanta, Ga., February 18, 1954.

The years of 1951, 1952, and 1953 have each produced widespread drouths throughout the so-called "humid areas" of the eastern United States. This fact, coupled with relatively high farm prices and the advent of lightweight portable pipe, has brought about a phenomenal growth in irrigation agriculture in this area. This expansion of irrigation from West to East certainly presents a number of problems of great interest to the engineer. These problems are worthy of recognition by such organizations as the American Society of Civil Engineers in order that they may contribute to the solution.

The 1940 census showed a total irrigated acreage in the 31 Eastern states of approximately 600,000 acres. The 1950 census gives a figure of 1,516,000 acres. This increase of 150 percent is all the more impressive because most of it occurred after the cessation of hostilities of World War II. It has been estimated by the Bureau of Agricultural Economics that the area being irrigated with sprinklers in the Eastern states has increased by over 200,000 acres since the 1950 census was taken.

The Sprinkler Irrigation Association quotes the following figures on shipments of aluminum irrigation tubing, which are indicative of the rapid growth of sprinkler irrigation: In 1946 — 1,279,000 pounds, and in 1953 — 27,700,000 pounds (estimated).

Many of us are inclined to think only of sprinkler irrigation when we speak of irrigation in the humid areas. Sprinkler irrigation has played, and will continue to play, a very large part in the growth of irrigation agriculture in the East. However, we should not overlook the fact that nearly 1,360,000 acres are irrigated in the humid areas of Arkansas, Louisiana, and Florida, using gravity or surface methods — that is, methods in which the irrigation water flows over or is ponded on the surface of the ground. The irrigation of rice, which makes up a large part of this acreage, presents many problems to the engineer interested in the conservation of soil and water. Engineers working on irrigation should have a good knowledge of the limitations and advantages of both surface and sprinkler irrigation. I believe the ultimate solution is the proper use of both methods, using each where it is best adapted.

One of the most critical problems confronting the engineer responsible for the design and installation of irrigation systems in the humid areas of the United States arises from the lack of sound basic data on which to base system design. It is unfortunate that irrigation research and the collection of basic information has failed to keep abreast of the phenomenal growth of irrigation agriculture here in the East. Some organized research has been started, but it will undoubtedly be some time before much usable information is made available to the engineer in the field. In the meantime, farmers are going to irrigate. And it is up to us as engineers to design and install their systems, based on the best information now available.

Research and investigations to improve irrigation practices have been carried on for about 50 years in the Western states. Out of these studies and experience, we have learned some basic principles of irrigation that will apply here in the Eastern states as well as the West. The basic principles of irrigation agriculture are generally the same, whether it be in a 50-inch or a 5-inch rainfall belt. The primary difference is in water management due to the variation in rainfall. This presents a problem of adapting established procedures to a different set of conditions, in order to bridge the gap between the rapid installation of irrigation systems and the obtaining of results of local research.

Some of the most urgent data needed by the field engineer for the preparation of a more adequate design in the humid areas are as follows:

1. Water Supply and Its Physical Control

A dependable water supply is essential to any irrigation system. Streams, lakes and ponds, and wells are the primary sources of supply. The tendency of most farmers in the humid areas to underestimate the water supply necessary for proper irrigation has brought about many unfortunate cases, where large investments were made in irrigation systems only to find that the water supply was entirely inadequate for the proper functioning of the system. Where storage reservoirs are used, the field engineer is confronted with a very difficult problem in estimating probable water yield. This applies particularly to small watersheds and small streams involved in the development of an individual farm irrigation system. Additional data on the availability of ground water would be useful in many areas.

This problem of water supply is closely tied to water laws and water rights. There is much additional work indicated in order to clarify this situation for the prospective water user.

2. Soil and Plant Moisture Relationships

Irrigation agriculture involves three basic elements — water, soil and plants. The payoff is through the plants and the ultimate effort is directed to the establishment of conditions for optimum crop production. A knowledge of interrelationships between water, soil, and plants is therefore essential. The soils must be classified with respect to their intake rates and water-holding capacities. The effect of tillage practices and crop rotations on these characteristics must be learned. Plant response to soil-moisture stress must be established. We need more data on the relationships between moisture and fertilizers. Root-zone depths and moisture-extraction patterns are also needed for the various crops being irrigated.

3. Irrigation Water Requirements

Before a water supply can be provided, or the system for conveying it determined, the quantities of water required to meet crop requirements must be established. These requirements depend on many factors, such as consumptive use by the plant, irrigation efficiency, quality of water, and method of delivery. The water supply and the distribution system must be designed to satisfy both the seasonal and maximum-use-period requirements.

Blaney and Criddle have developed a method for estimating irrigation water requirements. We have used this method in the humid areas with a reasonable degree of success. Since this procedure was originally developed for use in the West, however, it has been necessary to modify various factors. Additional field measurements of consumptive use and irrigation efficiencies are needed, especially insofar as the "peak consumptive use" figures are concerned.

4. Method of Water Application

The primary concern of the irrigation farmer is how to get his irrigation water into the storage space in the soil. It is a question of the physical application of the water. He must use a method which fits his crop, his soil, and his source of water — and in addition this method must satisfy the following criteria:

1. Uniform distribution of water over the entire field and throughout the entire root zone.

2. Maximum efficiency of water use, which means minimum surface run-off, minimum deep percolation loss, and minimum evaporation.
3. Minimum erosion.
4. Minimum labor and pumping costs.

5. Drainage

Whenever irrigation is practiced there are certain excess water applications which are unavoidable. Drainage systems should be designed to handle excess rainfall plus surplus irrigation water. What are the basic requirements of drainage in areas where heavy rainfall may follow the application of irrigation water? To what degree should adequate drainage be a basic design factor for irrigation systems?

When these questions are answered, the field engineer will have much more reliable information on which to base his design. But we should always keep in mind that, regardless of how good a design may be, the irrigation system will not operate successfully unless it is operated in accordance with the standards used in the original design. I have seen many well-designed sprinkler irrigation systems fail to do the job because they were not operated properly. We, as design engineers, should be fully conscious of this fact — that instructions in operation are essential to the success of a good design.

The old and widely used methods of irrigating when the crop changes color, when the leaves show some wilt, or at so-called critical stages of growth, are not the complete answer to the proper operation of an irrigation system. The farmers must be shown that the procedures involved in successful irrigation are based primarily on the physical properties of the soil — its depth; its intake rate; its water-holding capacity — in addition to the growth characteristics of the plant. We, as engineers, must emphasize the fact that the soil will primarily determine the answer to the two questions, "When do I irrigate?" and "How much do I put on?"

The present widely accepted concept of using irrigation as an "insurance" against drouth will in the long run do very little towards increasing crop production. Many farmers have operated on this basis and invariably they encounter the old adage of "too little and too late". The irrigation is started too late and, in order to cover the ground in a hurry, too little is applied. As a result, crops suffer and water is wasted. The yields have increased very little over normal yields without irrigation. Therefore, the dividends received from the investment in equipment, labor, and water supply are much smaller than the system is capable of producing.

Successful irrigation farmers have already accepted the fact that irrigation farming certainly involves a lot more than the application of water when crops begin to wilt. It should be the last step in a complete water management program, which includes control of soil erosion; removal of excess water, and the conservation and utilization of rainfall.

Studies conducted at Ithaca, New York, by the Department of Agriculture and the Cornell University Agricultural Experiment Station in 1950, 1951, and 1952 showed a greater forage yield on non-irrigated "high fertilization" plots than on irrigated "normal fertilization" plots. This is an indication that proper management alone could increase yields more than irrigation coupled with poor management. The results of this study are shown in Table 1.

Table 1. Forage yields and amounts of rainfall and irrigation.

	1950	1951	1952
Number of days*	126	125	137
Number of cuttings	6	7	8
Forage yields (oven-dry basis) — pounds per day, per acre			
"Normal" fertilization — rain only	14.3	20.0	27.9
— irrigated	18.7	27.0	42.0
"High" fertilization — rain only	44.9	55.6	55.2
— irrigated	48.4	60.6	61.6
"Mixed" fertilization — rain only	19.8	21.8	21.6
— irrigated	22.9	22.0	32.6
Rainfall in inches	17.6	13.9	14.4
Rainfall in inches per day	0.14	0.11	0.10
Rainfall plus irrigation in inches	21.1	20.4	23.4
Rainfall plus irrigation in inches per day	.17	.16	.17
Number of irrigations	4	6	7

*From date of fertilizer application in Spring to date of cutting in September. In 1950, May 9 to September 11; 1951, May 17 to September 18; and in 1952, April 25 to September 9.

Does humid area irrigation pay? Recent tests conducted cooperatively at Lewisburg, Tenn. by the Department of Agriculture dairy scientist and the Tennessee Agricultural Experiment Station, say yes:

"During the two years of the test, the irrigated half of the pasture averaged 54 percent more milk production per acre and 38 percent more income above costs than the non-irrigated plot. This amounts to an increase in net return from the irrigated pasture average $115.53 per acre."

Studies on irrigation of pasture for beef cattle production conducted by the University of Illinois, say no:

"During the five years of the tests, 6 irrigations were required annually and two inches of water were used for each one. Average annual costs for labor and gasoline were about $18.00 per acre. If the increase in gains is valued at 20 cents per 100 pounds, that would leave only $2.00 a year to cover such costs as depreciation and upkeep. But the depreciation on a $1,000 investment in equipment over a 10-year period at 3 percent compound interest would amount of about $27.00 an acre per year. With enough water, the same equipment could be used to irrigate four or five times as much land as the five acres included in these tests. That would reduce the fixed depreciation cost to about $6.00 an acre. But increased gains must be realized in order to pay the costs."

Such results are not necessarily conflicting after all of the factors involved are analyzed. But the tendency of many people to assume "that irrigation in humid areas does or does not pay" based on short-time results has been rather misleading and confusing to the prospective irrigator.

Such experiments must be conducted over a period of years and be specifically related to climate, soils, crops, and amounts and methods of applying irrigation water. It is logical to expect that varying results can and will be obtained from short-period studies, since the differences in yield over non-irrigated crops may be small during years of high rainfall. Crop quality may be the deciding factor in many instances. It is not difficult to anticipate a reduction in yield on poorly drained soils. Similar studies to those conducted at Illinois and at Lewisburg have already indicated some question concerning the feasibility of irrigating in humid areas unless adequate drainage is provided.

Generally speaking, the results of the many investigations that have been carried out and the results being obtained by the thousands of farmers who have invested in irrigation systems seem to indicate that humid-area irrigation, when properly done, does pay good dividends through increased yields and better crop quality.

A serious obstacle in the path of future development of irrigation in the humid areas is the present status of the laws covering the use of water for irrigation. Nearly all of the Eastern states operate under the legal concept known as the riparian doctrine. According to this doctrine, every owner whose property touches a stream or lake has riparian rights. Riparian owners enjoy a right to have water flow by or through their lands undiminished in quantity except for use by up-stream owners for domestic purposes.

Some states have adopted a modified riparian doctrine which permits the use of water for irrigation purposes, but even in most of these states there is no provision for rights of prior appropriation. A farmer who has been practicing irrigation for many years has no protection should his neighbors upstream follow his example and start to irrigate from the same water supply. Such action may deprive him of a large portion of his water supply, but under existing law he would not have established any priority in rights over these later users.

Some states are giving serious consideration to the enactment of more adequate water laws to protect the irrigation farmer. South Carolina, I understand, has taken the lead in this field and has already passed a new water law that recognizes this problem of irrigation. Until this is done in all of the Eastern states, the farmer who invests in an irrigation system is taking definite risks. As Raleigh Barlowe of Michigan States College stated:

"(1) He is not always sure he has the right to take water for irrigation.
"(2) His operations may be stopped by injunction if his actions cause material damage to other riparian users.
"(3) He may lose much of his investment if upper riparian owners decide to irrigate from his already limited supply."

The use of wells and the storage of surface water before it reaches a well defined stream, lake, or pond offer a lesser risk in most states. In many states, the rule of "reasonable use" covers the use of underground waters and this water can be used for irrigation providing there is no adverse effect on other users.

The riparian doctrine, strictly interpreted, is not compatible with irrigation. It is very difficult, therefore, to visualize a real large-scale expansion of

irrigation farming in the Eastern states until each state spells out and clarifies the rights that irrigators have to the use of water for the irrigation of farm crops.

The problems confronted in the development of irrigation in the humid Eastern states is twofold. On the one hand are the needs for proper design of irrigation systems and their proper operation. On the other are the needs for the development of water laws that are compatible with the needs of irrigation —and, incidentally, compatible with the growing needs for water by industry and municipalities. The Nation's engineers have a major part to play in the solution of both types of problems.

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The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

VOLUME 79 (1953)

JULY:[a] 200(SM)[b], 201(ST)[b], 202(EM)[b], 203(SM)[b], 204(AT)[b], 205(EM)[b], 206(ST)[b], 207(SA)[b], 208(SA)[b], 209(ST)[b], 210(SU)[b], 211(EM)[b], 212(SU)[b], 213(IR)[b], 214(HW)[b], 215(SM)[b], 216(ST)[b], 217(ST)[b], 218(ST)[b], 219(ST)[b], 220(SM)[b], 221(HW)[b], 222(SM)[b], 223(EM)[b], 224(EM)[b], 225(EM)[b], 226(CO)[b], 227(SM)[b], 228(SM)[b], 229(IR)[b].

AUGUST: 230(HY), 231(SA), 232(SA), 233(AT), 234(HW), 235(HW), 237(AT), 238(WW), 239(SA), 240(IR), 241(AT), 242(IR), 243(ST), 244(ST), 245(ST), 246(ST), 247(SA), 248(SA), 249(ST), 250(EM)[c], 251(ST), 252(SA), 253(AT), 254(HY), 255(AT), 256(ST), 257(SA), 258(EM), 259(WW).

SEPTEMBER: 260(AT), 261(EM), 262(SM), 263(ST), 264(WW), 265(ST), 266(ST), 267(SA), 268(CO), 269(CO), 270(CO), 271(SU), 272(SA), 273(PO), 274(HY), 275(WW), 276(HW), 277(SU), 278(SU), 279(SA), 280(IR), 281(EM), 282(SU), 283(SA), 284(SU), 285(CP), 286(EM), 287(EM), 288(SA), 289(CO).

OCTOBER:[d] 290(all Divs), 291(ST)[c], 292(EM)[c], 293(ST)[c], 294(PO)[c], 295(HY)[c], 296(EM)[c], 297(HY)[c], 298(ST)[c], 299(EM)[c], 300(EM)[c], 301(SA)[c], 302(SA)[c], 303(SA)[c], 304(CO)[c], 305(SU)[c], 306(ST)[c], 307(SA)[c], 308(PO)[c], 309(SA)[c], 310(SA)[c], 311(SM)[c], 312(SA)[c], 313(ST)[c], 314(SA)[c], 315(SM)[c], 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

NOVEMBER: 321(ST), 322(ST), 323(SM), 324(SM), 325(SM), 326(SM), 327(SM), 328(SM), 329(HW), 330(EM)[c], 331(EM)[c], 332(EM)[c], 333(EM)[e], 334(EM), 335(SA), 336(SA), 337(SA), 338(SA), 339(SA), 340(SA), 341(SA), 342(CO), 343(ST), 344(ST), 345(ST), 346(IR), 347(IR), 348(CO), 349(ST), 350(HW), 351(HW), 352(SA), 353(SU), 354(HY), 355(PO), 356(CO), 357(HW), 358(HY).

DECEMBER: 359(AT), 360(SM), 361(HY), 362(HY), 363(SM), 364(HY), 365(HY), 366(HY), 367(SU)[e], 368(WW)[e], 369(IR), 370(AT)[e], 371(SM)[e], 372(CO)[e], 373(ST)[e], 374(EM)[e], 375(EM), 376(EM), 377(SA)[e], 378(PO)[e].

VOLUME 80 (1954)

JANUARY: 379(SM)[e], 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)[e], 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)[e], 390(HY), 391(IR)[e], 392(SA), 393(SU), 394(AT), 395(SA)[e], 396(EM)[e], 397(ST)[e].

FEBRUARY: 398(IR)[f], 399(SA)[f], 400(CO)[f], 401(SM)[e], 402(AT)[f], 403(AT)[f], 404(IR)[f], 405(PO)[f], 406(AT)[f], 407(SU)[f], 408(SU)[f], 409(WW)[f], 410(AT)[f], 411(SA)[f], 412(PO)[f], 413(HY)[f].

MARCH: 414(WW)[f], 415(SU)[f], 416(SM)[f], 417(SM)[f], 418(AT)[f], 419(SA)[f], 420(SA)[f], 421(AT)[f], 422(SA)[f], 423(CP)[f], 424(AT)[f], 425(SM)[f], 426(IR)[f], 427(WW)[f].

APRIL: 428(HY)[e], 429(EM)[e], 430(ST), 431(HY), 432(HY), 433(HY), 434(ST).

MAY: 435(SM), 436(CP)[e], 437(HY)[e], 438(HY), 439(HY), 440(ST), 441(ST), 442(SA), 443(SA).

JUNE: 444(SM)[g], 445(SM)[g], 446(ST)[g], 447(ST)[g], 448(ST)[g], 449(ST)[g], 450(ST)[g], 451(ST)[g], 452(SA)[g], 453(SA)[g], 454(SA)[g], 455(SA)[g], 456(SM)[g].

JULY: 457(AT), 458(AT), 459(AT)[e], 460(IR), 461(IR), 462(IR), 463(IR)[e], 464(PO), 465(PO)[e].

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a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.
b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.
c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
e. Discussion of several papers, grouped by divisions.
f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
g. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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